10062

DRAFT

Ophitic Ilmenite Basalt

78.5 grams

Figure 1: Closeup photo of 10062,13 showing vugs in ilmenite basalt. This is the largest remaining piece (25g). NASA#S76-21515. Scale in mm.

Introduction

10062 is an old, low-K, high-Ti basalt from Apollo 11. Based on texture and composition, James and Wright (1972) termed 10062 an ophitic ilmenite basalt whereas Gamble et al. (1978) describe the texture as subophitic (figure 1). It has been found to be one of the oldest of the mare basalts (other than those found as clasts in breccias).

Petrography

Carter and MacGregor (1970), Beaty and Albee (1978), Gamble et al. (1978) and Kramer et al. (1977) provide petrographic descriptions of 10062. The texture is ophitic, with radiating lath-like and acicular crystals of plagioclase, intergrown with tabular and skeletal crystals of ilmenite, irregular grains of zoned clinopyroxene and olivine (figure 2). Late stage silica, fayalite, ulvöspinel, troilite and apatite are present in the mesostasis. The average grain size is about 0.1-0.2 mm indicating that this rock has been quickly cooled.

The abundance of ilmenite is striking, with some grains as large as ~ 1 mm. Some ilmenite has relict cores of armalcolite, which appears to have been replaced and overgrown by ilmenite.

The origin of high-Ti basalts has been discussed by many authors (see for example Walker et al. 1975). Since 10062 is about the same age as 10003 and 10029 (Papanastassiou et al. 1977), and has similar mineralogy, chemistry and texture, Beaty and Albee (1978) and Gamble et al. (1978) have concluded these three samples may be related to each other.

Figure 2: Photomicrograph of thin section of 10062 showing ophitc texture. Field of view about 2 mm.

Mineralogy

Olivine: Carter and MacGregor (1970) and Beaty and Albee (1978) report olivine compositions ranging Fo_{76-50}. Rounded grains of olivine are often included in clinopyroxene suggesting a reaction relationship.

Pyroxene: Hollister and Hargraves (1970) describe the compositional zoning of pyroxene in 10062. Pigeonite appears to be exsolved on a fine scale. Pyroxene compositions were given by Beaty and Albee (1978) (figure 3).

Plagioclase: The composition of plagioclase is An_{94-80} (Beaty and Albee 1978).

Ilmenite: Ilmenite crystals in 10062 are lath-shaped, often skeletal, and up to 1600 microns in long dimension (Gamble et al. 1978). Carter and MacGregor (1970) found lamellae of rutile and blebs of spinel exsolved from the larger grains of ilmenite.

Armalcolite: LSPET (1969) and Carter and MacGregor (1970) reported rounded grains of dull grey armalcolite in the cores of ilmenite grains.

Silica: Cristobalite is present in abundance (5%) in 10062.

Mineralogical Mode

	Carter and MacGregor 1970	Gamble et al. 1978	Beaty and Albee 1978
Olivine	5 vol. %	4.3	5.0
Pyroxene	52	42.8	39
Plagioclase	24	33.7	37.6
Ilmenite	18	14.2	12.5
Cristobalite	tr.	2.4	4.6
Mesostasis	1	1.9	0.6

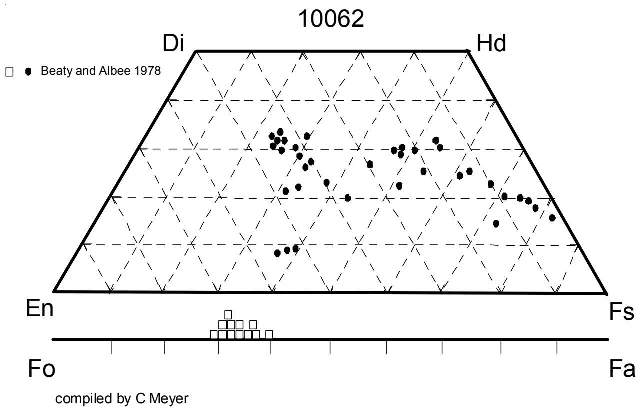

Figure 3: Olivine and pyroxene composition for 10062 (data replotted from Beaty and Albee 1977).

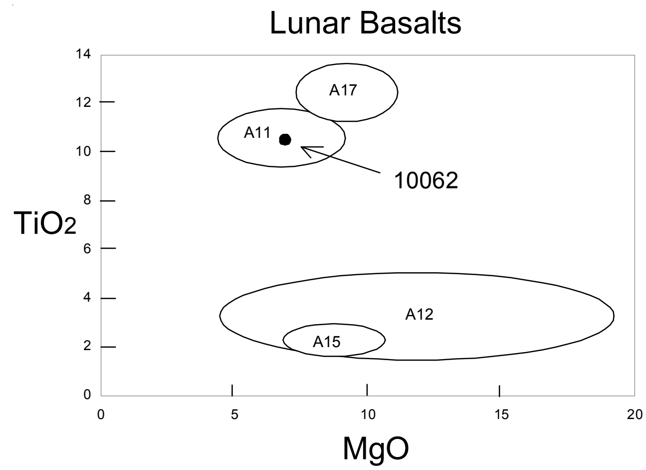

Figure 4: Lunar basalt sample 10062 is a typical high Ti basalt.

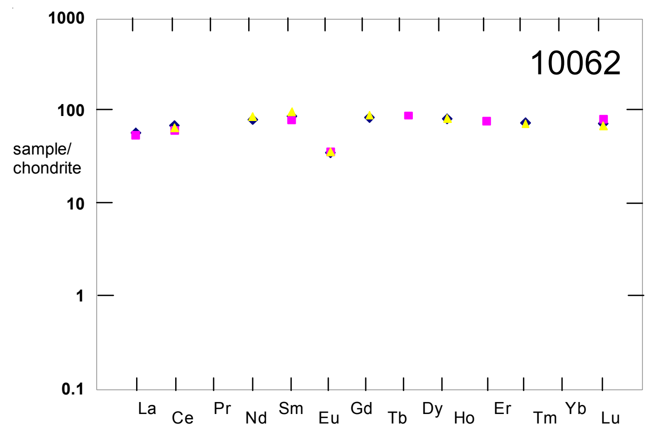

Figure 5: Normalized rare-earth-element diagram for 10062 (data from Gast et al. 1970, Goles et al. 1970, and Philpotts et al. 1970). Note the slight depletion of La and Ce.

Chemistry

10062 is a high-Ti, low-K Apollo 11 basalt (figure 4). The chemical composition of 10062 is tabulated in table 1. The rare earth elements (REE) and large ion lithophile elements (LIL) are depleted with respect to the high-K, Apollo 11 basalts (see section on 10057). There is a hint that La and Ce are also slightly depleted with respect to the other REE (figure 5).

Radiogenic age dating

Turner (1970) dated 10062 by the Ar-Ar plateau method as 3.82 b.y., making this the oldest mare basalt (10003 and 10029 may be nearly as old). Papanastassiou et al. (1977) dated 10062 by Rb-Sr and Sm-Nd isochron methods and determined an even older age (figures 6 and 7). Other low-K, high-Ti Apollo 11 basalts are slightly younger and may be from a different flow(s).

Cosmogenic isotopes and exposure ages

Turner et al. (1970) reported an exposure age of 90 m.y. by ^{38}Ar.

Other Studies

O'Hara et al. (1974) experimentally determined the liquid composition of 10062 (at 1120 deg. C) cotectic with olivine, clinopyroxene, anorthite and ilmenite at low pressure and made the case for the hypothesis that mare basalts are slowly consolidated giant lava lakes and not the result of partial melting of the deep lunar interior! However, Walker et al. (1975) review the origin of titaniferous lunar basalts by partial melting and conclude that the preferred source region is a "late-stage ilmenite-rich cumulate produced from the residual liquid of the primordial differentiation of the outer portion of the Moon."

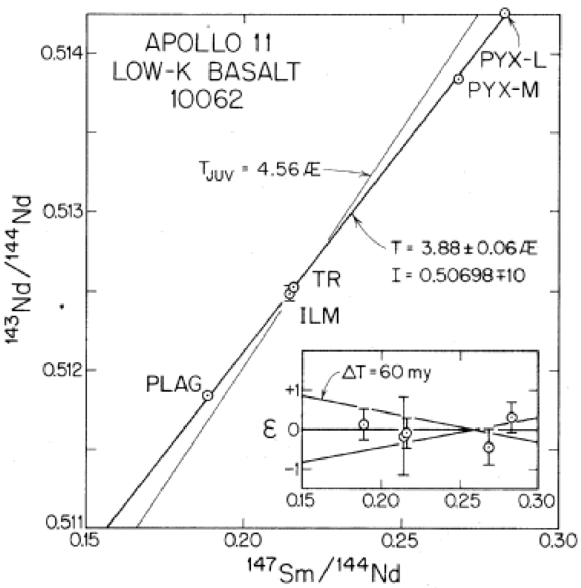

Figure 6: Sm-Nd internal mineral isochron of mare basalt 10062 (from Papanastassiou et al. 1977).

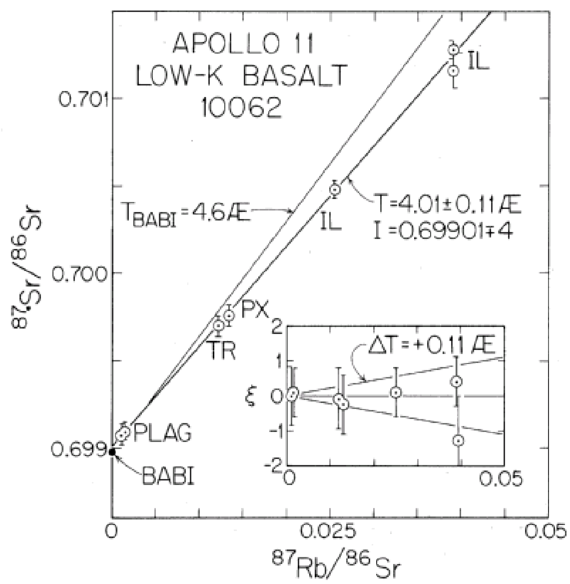

Figure 7: Rb-Sr internal mineral isochron of mare basalt 10062 (from Papanastassiou et al. 1977).

Summary of Age Data for 10062

	Ar-Ar plateau	Rb-Sr	Sm-Nd
Turner et al. 1970	3.82 ± 0.06		
Papanastassiou et al. 1977		4.01 ± 0.11	3.88 ± 0.06

Table 1. Chemical composition of 10062.

reference	Compston 70		Gast 70		Rose 70		Goles 70		Philpotts 70		Turekian 70	Kharkar 71	
weight													
SiO2 %	39.8	(a)			38.8	(a)							
TiO2	10.74	(a)	10.7	(b)	10.3	(a)						11.5	(c)
Al2O3	10.22	(a)			12.1	(a)							
FeO	19.22	(a)			18.3	(a)					16.7	18.01	(c)
MnO	0.3	(a)			0.27	(a)	0.23	(c)			0.19	0.26	(c)
MgO	7.08	(a)			7.21	(a)							
CaO	11.47	(a)	10.8	(b)	12	(a)						11.6	(c)
Na2O	0.41	(a)	0.44		0.69	(a)	0.42	(c)			0.4	0.4	(c)
K2O	0.08	(a)	0.076	(b)	0.07	(a)			0.07	(b)	0.03		(c)
P2O5	0.12	(a)											
S %	0.16	(a)											
sum	99.6												
Sc ppm							74.7	(c)			76	86	(c)
V							75	(c)					
Cr							1540	(c)			1410	1660	(c)
Co							13.8	(c)			13	13	(c)
Ni			13	(b)							15		(c)
Cu											4		(c)
Zn			11	(b)									
Ga	3	(a)											
Ge ppb													
As													
Se											0.23		(c)
Rb	0.89	(a)	0.9	(b)					0.832	(b)			
Sr	187.8	(a)	141.6	(b)					194	(b)			
Y	103	(a)											
Zr	319	(a)					290	(c)					
Nb													
Mo											0.16		(c)
Ru													
Rh													
Pd ppb													
Ag ppb											80		(c)
Cd ppb													
In ppb													
Sn ppb													
Sb ppb													
Te ppb													
Cs ppm													
Ba			79.9	(b)			230	(c)	134	(b)			
La			13.8	(b)			13.1	(c)			12	11.5	(c)
Ce			42.7	(b)			38	(c)	40.2	(b)	48	37.6	(c)
Pr													
Nd			37	(b)					39.9	(b)			
Sm			13.3	(b)			11.9	(c)	14.7	(b)	10	8.7	(c)
Eu			2.02	(b)			2.07	(c)	2.07	(b)	1.8	2.2	(c)
Gd			17.2	(b)					18.1	(b)			
Tb							3.3	(c)					
Dy			20.4	(b)					20.6	(b)	22	24.6	(c)
Ho							4.4	(c)					
Er			12	(b)					11.8	(b)			
Tm													
Yb			12.1	(b)			13.5	(c)	11.3	(b)	6.3	7.8	(c)
Lu			1.73	(b)			1.94	(c)	1.76	(b)	0.87	1.7	(c)
Hf							11.8	(c)			10	11.9	(c)
Ta							1	(c)			1.8	1.7	(c)
W ppb													
Re ppb													
Os ppb													
Ir ppb													
Pt ppb													
Au ppb											5.8		(c)
Th ppm	0.9	(a)											
U ppm							0.27	(c)			0.28		(c)

technique (a) XRF, (b) IDMS, (c) INAA